Jet Propulsion Laboratory
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Game Changing Antenna Technologies Enabling New Class of Earth Science and Interplanetary Mission

Antenna Technologies

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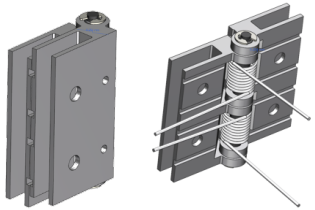
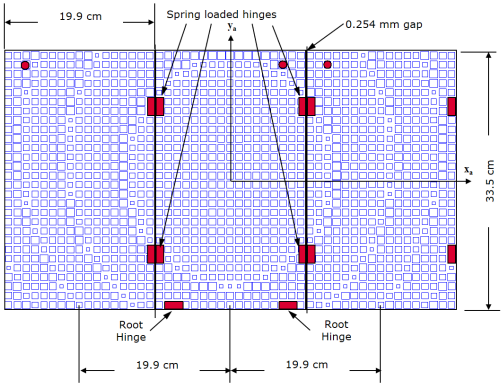
Mars Cube One: MarCO

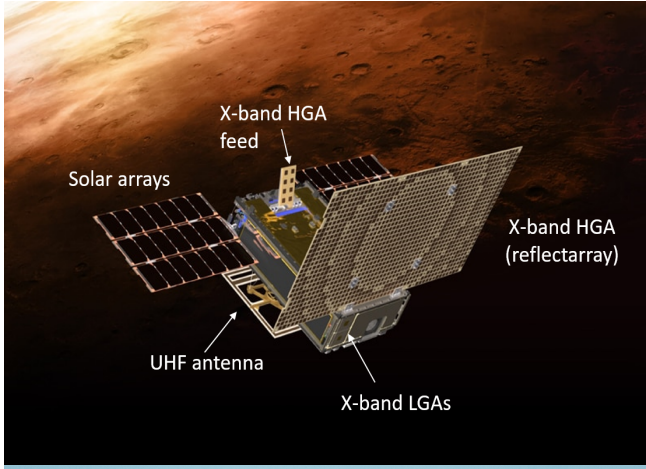
- **Challenge**: bent pipe communication at 1.04AU from Earth – i.e. receive and transmit at the same data rate (8kbps)

- **Drastic requirements:**
  - Stowage volume: 12.5mm × 210mm × 345mm
  - Gain of at least 28dBic (required aperture: 335mm × 587mm)



Custom made hinges



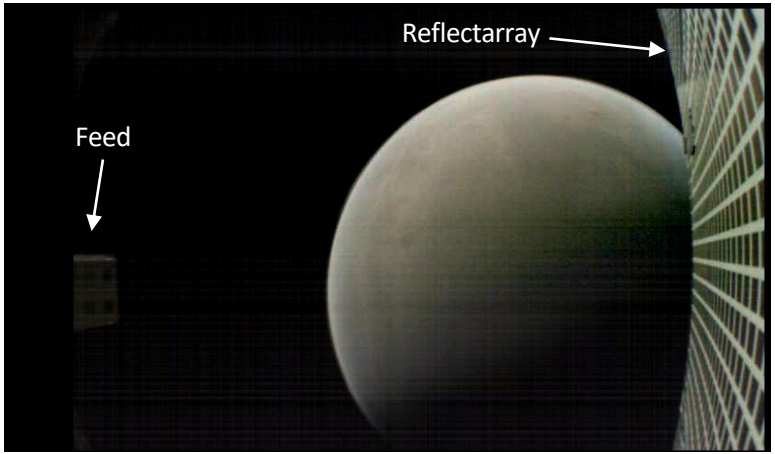


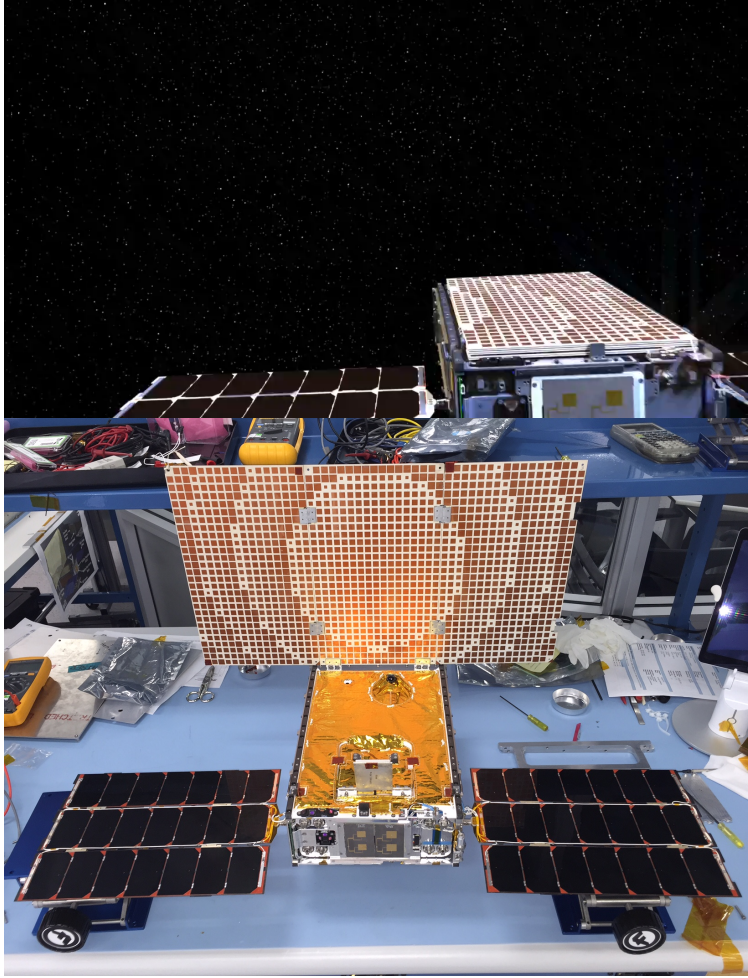
Patented technology: "Deployable reflectarray high gain antenna for satellite applications", US #15/204,951, July 7, 2016.

Mars Cube One: MarCO

- **Demonstrated in Space**:
  - Successful deployment of two antennas in space
  - Quick gain assessment has shown that the gain is within ±0.4dB.
  - Pattern successfully verified in space

- **An historical deployment witnessed by a picture**





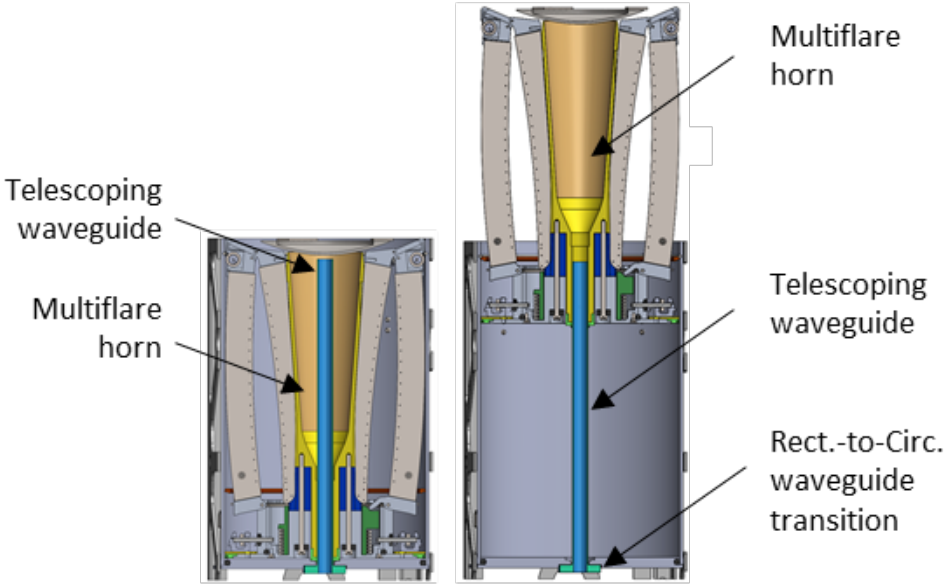
RainCube: Radar in a CubeSat

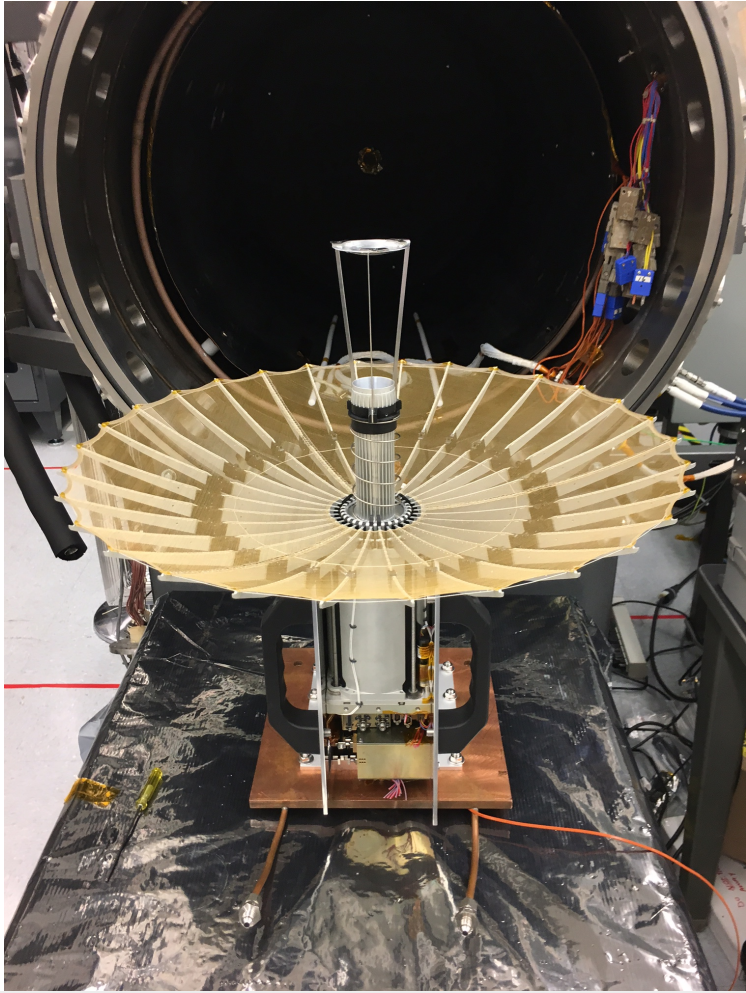
- 0.5-m reflector Ka-band antenna
- Polarization: V-polarization
- Gain: 42.6 dBi
- Efficiency: 56%
- HPBW: **0.57˚➔ footprint = 8.0km**
- Key RF innovation:
  - Compensation of the non parabolic shape
  - Telescoping waveguide
  - 40 opening per inch (OPI) mesh reflector
  - Capability of modeling accurately the Ka-band antenna including the shape distortion and OPI

N. Chahat, R. E. Hodges, J. Sauder, M. Thomson, E. Peral and Y. Rahmat-Samii, "CubeSat Deployable Ka-Band Mesh Reflector Antenna Development for Earth Science Missions," *IEEE Trans. Antennas & Propag.*, vol. 64, no. 6, pp. 2083-2093, June 2016.

RainCube: Radar in a CubeSat

- Antenna description:

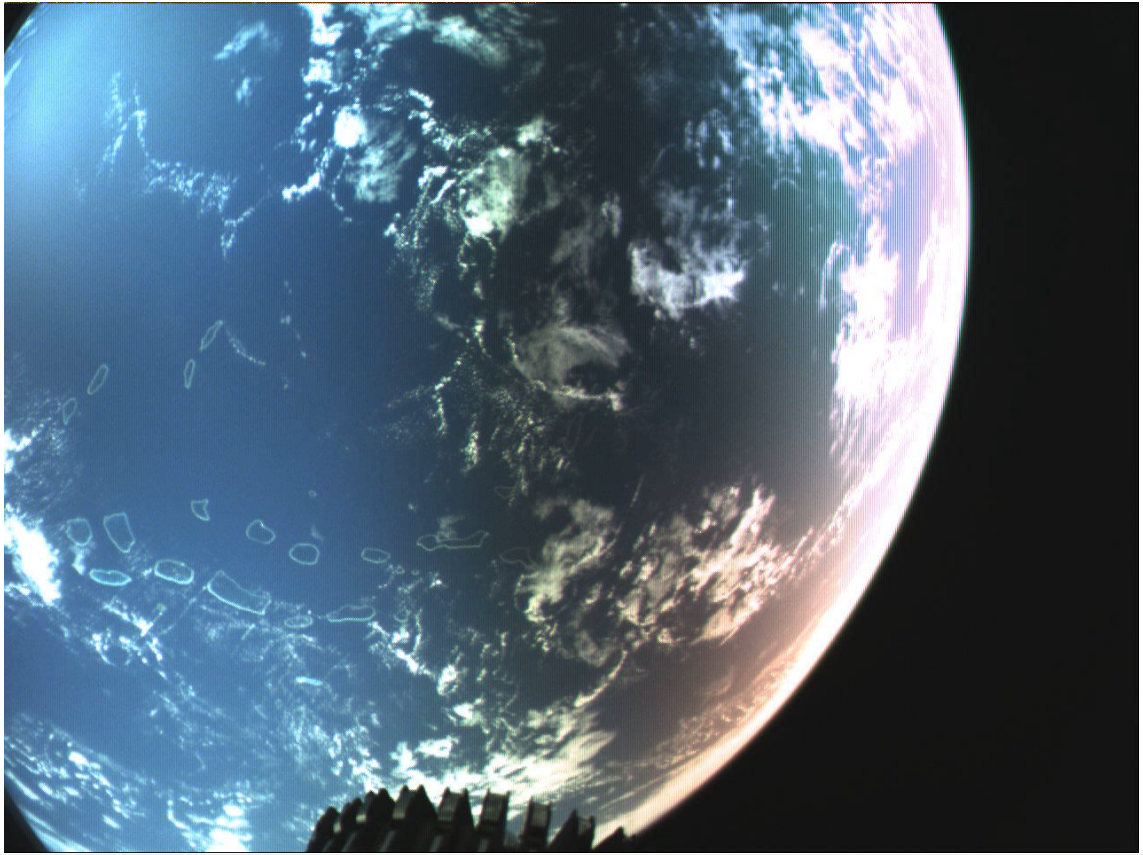




N. Chahat, R. E. Hodges, J. Sauder, M. Thomson, E. Peral and Y. Rahmat-Samii, "CubeSat Deployable Ka-Band Mesh Reflector Antenna Development for Earth Science Missions," *IEEE Trans. Antennas & Propag.*, vol. 64, no. 6, pp. 2083-2093, June 2016.

RainCube: Radar in a CubeSat

- **Successful demonstration in Space:**

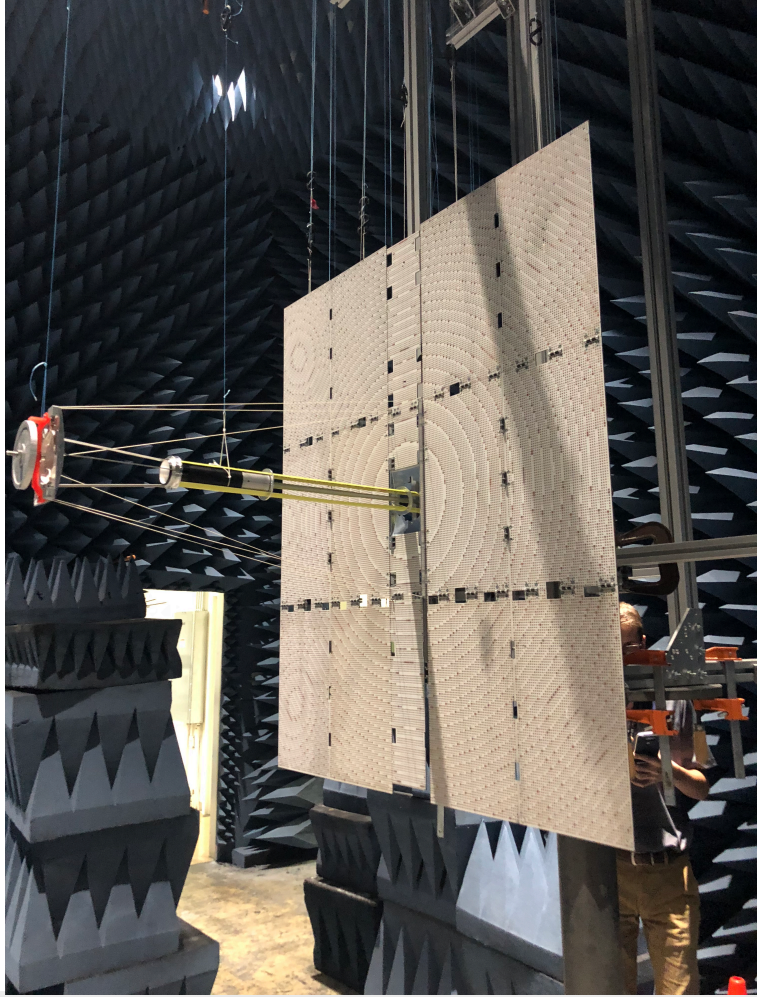


OMERA: One Meter ReflectArray

- 1-m reflector Ka-band antenna (98.6cm x 82.1cm)
- Polarization: V-polarization
- Gain: 48.0 dBi
- Efficiency: 47%
- HPBW: **0.28˚➔ footprint = 3.9km**

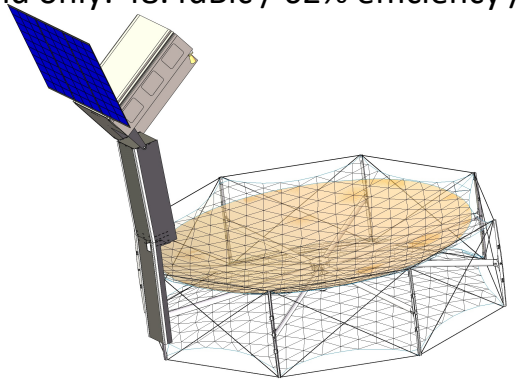
- **Benefits:**
  - Smaller footprint for more powerful radar (2 times smaller compared to Raincube)
  - 8x higher data rates (64kbps from Mars at 1AU)

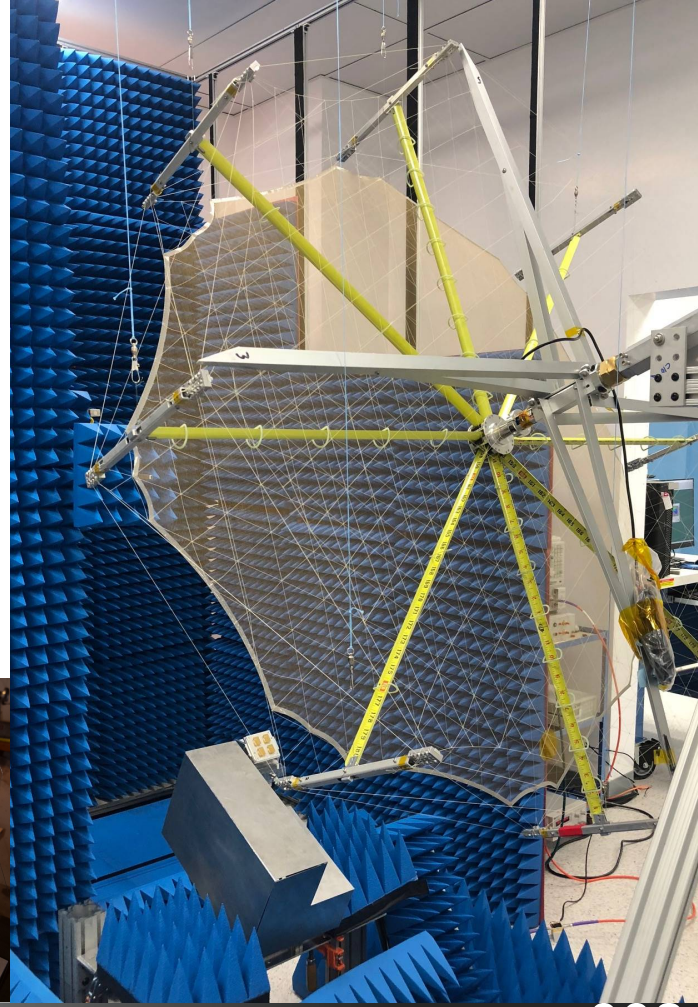
Patent filed: “One Meter Deployable Reflectarray Antenna for Earth Science Radars or Telecommunication Systems”.



Mesh reflector: Enabling higher data rates for CubeSats

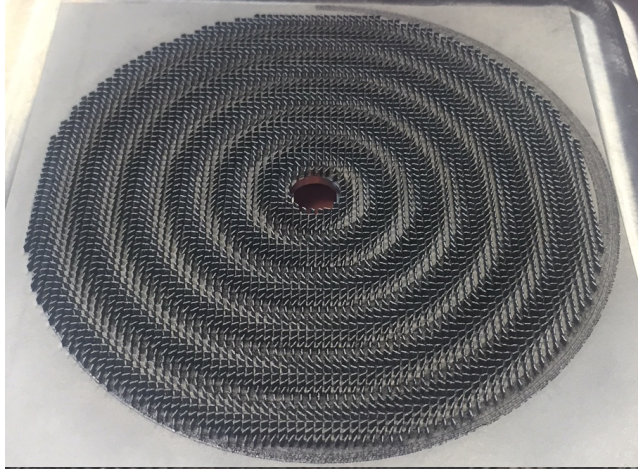
- New deployable mesh reflector addressing a clear telecommunication need for Small Sat / CubeSats for higher data rates
- Covers both X-band and Ka-band (very unlikely to need both at the same time so we are offering the 3 options: X-band only, Ka-band only, X/Ka-band)
  - ❑ X-band only: 36.1dBic / 72% efficiency / 64kbps at 1AU
  - ❑ Ka-band only: 48.4dBic / 62% efficiency / 128kbps at 1AU

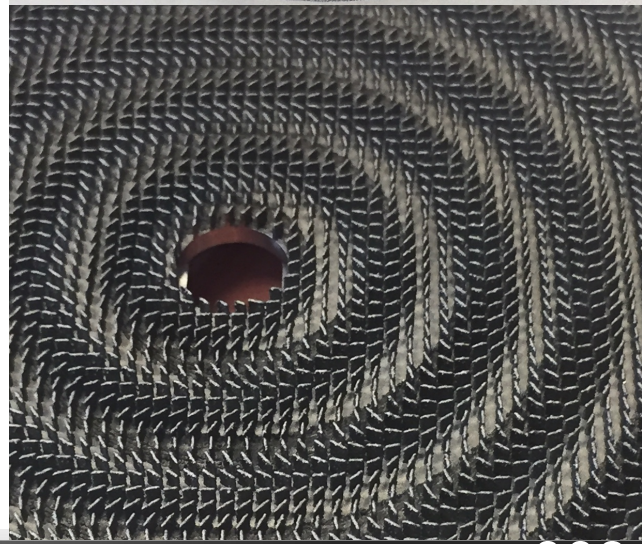




Metasurface antenna: the future is flat

- Flat metasurface antenna for telecommunication at Ka-band
- Polarization: RHCP
- Gain: 26dBi
- Efficiency: 40%
- Key RF innovation:
  - Integrated feed on flat antenna
  - All metal (no dielectric needed)
  - 3D printed antenna
  - Developed in-house s/w (no commercially available solution)
- **Advantages**:
  - Could simplify the deployment complexity of large structure
  - RF performance remains stable over thermal
  - Can sustain high radiation levels
  - Any radiation pattern can be obtained from a flat surface
  - Perfect candidate for platforms with limited stowage volume

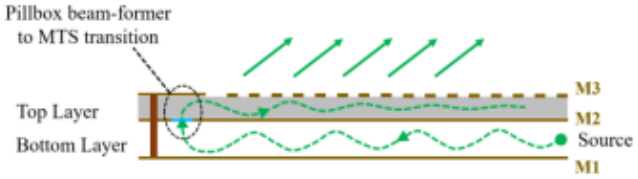


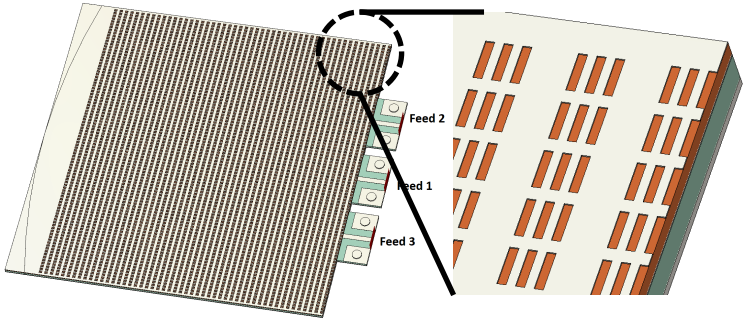


D. González-Ovejero, N. Chahat, R. Sauleau, G. Chattopadhyay, S. Maci and M. Ettorre, "Additive Manufactured Metal-Only Modulated Metasurface Antennas," in *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 11, pp. 6106-6114, Nov. 2018.

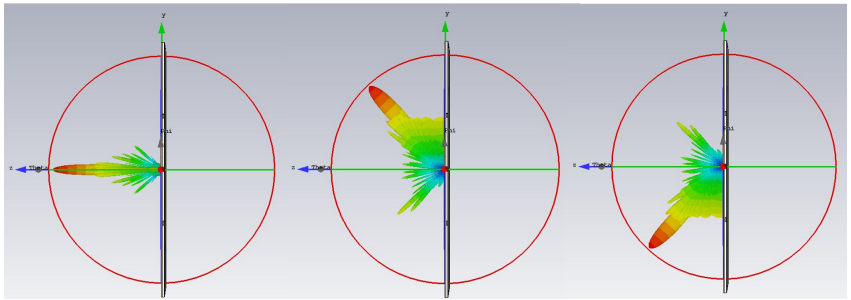
Metasurface antenna: Beam Steering in Progress

- Flat metasurface antenna at W-band funded by an ACT.
- Gain: 31dBi
- **Key RF innovation**:
  - Pill-box design for steering in φ-direction
  - GaAs Schottky diodes on metasurface steering in θ-direction
- **Advantages**:
  - Flat antenna technology with steering capabilities

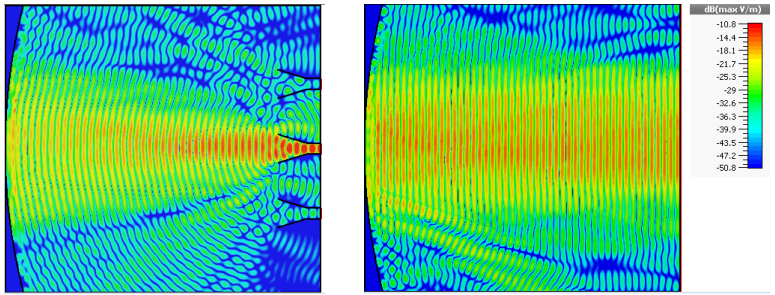




Feed 1 for φ=0° Feed 2 for φ=45° Feed 3 for φ=-45°



E-Field (Silicon Layer) ***E-Field (GaAs Layer)***

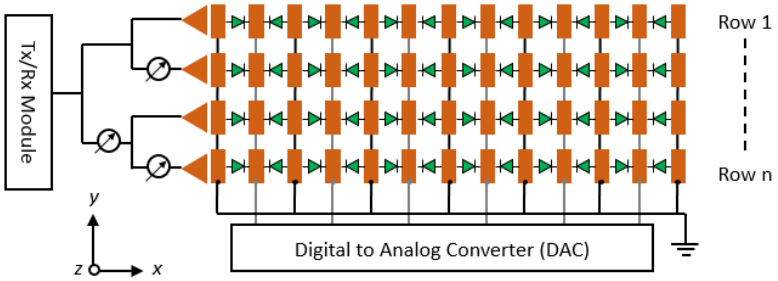


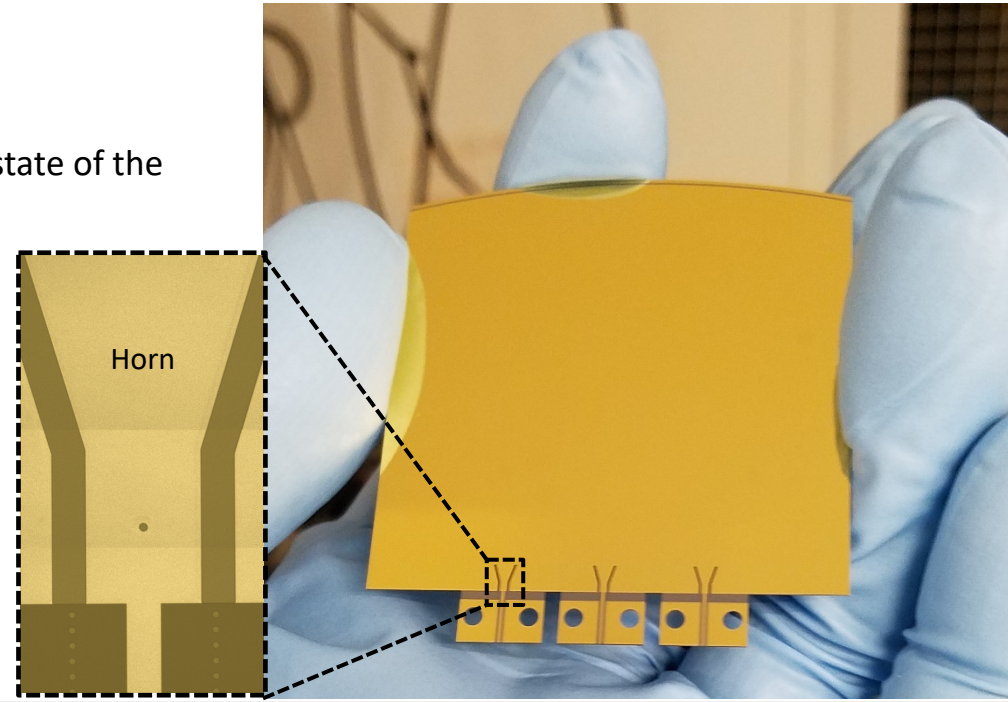
Metasurface antenna: Beam Steering in Progress

- **Fabrication**:
  - Silicon (Si) / Gallium Arsenide (GaAs) semiconductor fabrication technique.

- **CMOS technology:**
  - CMOS chip (JPL design) will be used to control the state of the diodes (on / off) to provide full 3D beam steering

    ➔ low cost antenna technology with potential commercial applications





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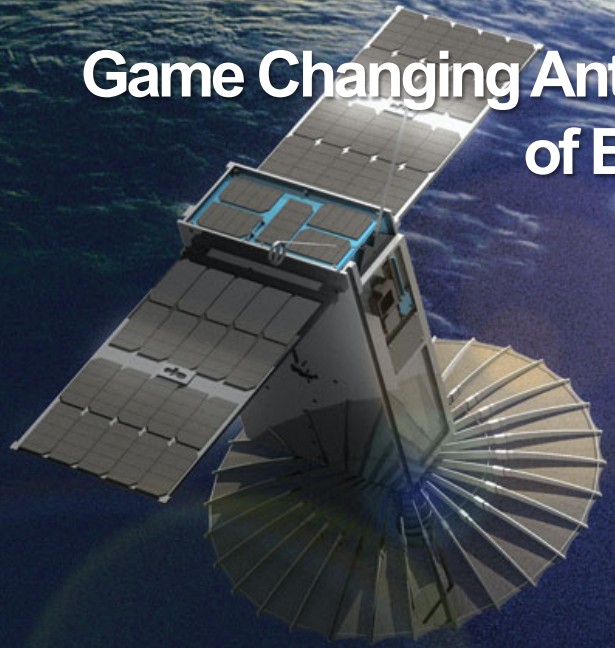

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Questions?

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